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Request for grant of a patent

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1. Your reference — P36034GB/LBA/GWI/GMU

2. Patent application number *(The Patent Office will fill in this part)* — 23 APR 2004 — 0409065.0

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

Lloyd (Scotland) Limited
152 Bath Street
Glasgow
G2 4TB

Patents ADP number *(if you know it)* 8776932001

If the applicant is a corporate body, give the country/state of its incorporation — United Kingdom

4. Title of the invention — Body Protecting Device

5. Name of your agent *(if you have one)*

Murgitroyd & Company

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Scotland House
165-169 Scotland Street
Glasgow
G5 8PL

Patents ADP number *(if you know it)* 1198015

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*

a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	
Description	13
Claim *(s)*	4
Abstract	1
Drawing *(s)*	4

10. If you are also filing any of the following, state how many against each item.

Priority documents	-
Translations of priority documents	-
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	-
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	-
Any other documents *(please specify)*	-

11. I/We request the grant of a patent on the basis of this application.

Signature Murgitroyd & Company Date 22 April 2004

Murgitroyd & Company

12. Name and daytime telephone number of person to contact in the United Kingdom: GLEN WILSON 0141 307 8400

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Body Protecting Device

The present invention relates to body protecting devices. In particular, but not exclusively, the invention relates to the energy absorbing materials used in devices having a relatively large curvature such as safety helmets, elbow pads, knee pads, shoulder pads and the like, and methods of forming such materials.

Many body protecting devices have a large curvature, κ, which is defined as the inverse of the radius of curvature, ρ, for the device. The device, such as a safety helmet, may require a permanently curved shape. Other devices, such as pads for elbows, knees and shoulders, may have to be sufficiently flexible to elastically adopt such a curved shape in response to movements of the body. Suitable materials and forming methods must be used for these devices.

Crash helmets conventionally comprise a substantially spheroidal outer skin of tough plastics material and an inner skin of resilient material such as a hard foam. The rigid outer skin transmits an impact load more evenly to the inner skin which absorbs the energy imparted by the impact load. The helmets are formed in a female mould, or around a male mould, and the materials must undergo significant curvature to form the spheroidal shape. Also, the outer and inner skins must be inserted separately to the mould. Otherwise, during bending, the bond between the two materials would prevent the necessary slippage of the outer skin (which is stretched) relative to the inner skin (which is compressed), or else would produce high planar stresses at the internal and external surfaces.

It may be desirable to decrease the total mass of the helmet. Also, the methods of forming the helmets, which typically involve hand lay-up, tend to be complex and expensive. It would be advantageous to be able to insert the inner and outer skin as a one-piece material within the mould.

Axially loaded columns of various cross sectional shapes have been used for some time to improve the structural crashworthiness of vehicles, roadside furniture and the like. Metal columns exhibit a multiple buckling and folding failure mode which is effective in absorbing impact energy. Plastic and composite columns have a number of failure modes but

all of the modes typically involve progressive crushing of one end of the column.

The performance and failure mode of plastic and composite columns depends on a complex interaction of a number of different parameters including the material used, the geometry (shape and thickness), fibre alignment in composites, the use of triggers, and the loading conditions. However, a careful selection of these parameters can result in a safety device which outperforms the metal equivalent.

Regardless of the material used, arrays of columns arranged parallel to the load have generally been found to increase energy absorbing performance and improve the stability of the safety device. Columns tend to produce a relatively constant level of energy absorption as the column is progressively buckled of crushed. Axially loaded cones have been found to produce a more linearly increasing rate of energy absorption which can often be more desirable in crash situations.

Sandwich panels, consisting of two tough outer skins separated by a core material having a lower stiffness, have been used in many applications such as building components and structural panels for road vehicles and aircraft. A popular core consists of a honeycomb structure, that is an array of longitudinal members, each member having a hexagonal cross-section. The axis of each longitudinal member is normal to the plane of the inner and outer skins

and each end of each longitudinal member is typically bonded to the respective skin. Therefore, the honeycomb structure represents an array of columns arranged parallel to a load which impacts the plane of one of the outer skins.

WO 94/00031 discloses a safety helmet which includes a honeycomb sandwich structure. Generally, a hand lay-up method is used. EP 0881064 discloses a protective element which also has a honeycomb sandwich structure. The document states that the element may be incorporated within a wide range of protective clothing which includes helmets.

Honeycomb structures are suitable for applications involving flat panels or structures with only a relatively small curvature. However, problems arise when the material is used in items having a large curvature.

Each hexagonal cell of the honeycomb structure has a rotation symmetry angle of $n.60°$. The cell therefore does not have rotation symmetry about an angle of 90°. The cell is therefore not orthotropic, that is it has a different response to a load applied at a first angle than to a load applied at a second angle which is applied at 90° from the first angle. When forming a helmet, the material is bent around a mould about two orthogonal axis to form the spheroidal shape. Therefore, a hexagonal structure can create difficulties when trying to achieve the curvature desired.

Furthermore, a hexagonal structure is by nature anticlastic, in that a positive curvature about an axis results in a negative curvature about an orthogonal axis (the shape of a saddle illustrates this phenomenon). This again leads to difficulties in the forming process.

Furthermore, there are disadvantages in using a honeycomb structure for devices such as pads which must elastically deform to a large curvature. These disadvantages include the relatively rigid nature of the structure. A hexagonal element can be considered to be six flat plates, each of which are rigidly fixed at each longitudinal edge. It is known theoretically and empirically that such elements, and structures produced from these elements are relatively inflexible. A pad produced from such a material can tend to feel stiff and less comfortable. It is desirable that comfort be improved without any sacrifice in the energy absorbing capability of the device.

According to a first aspect of the present invention there is provided a body protecting device comprising:

a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

The term "tube" is used to denote a hollow cylindrical or conical structure, preferably a circular cylindrical or circular conical structure.

The tubular array results in a material which is substantially isotropic and substantially non-anticlastic.

Preferably the body protecting device comprises a safety helmet. Alternatively, the body protecting device comprises a safety pad.

Preferably each tube has a diameter of between 2 and 8 mm.

Preferably the first material has, or can deform to, a large curvature.

Preferably the first material comprises polycarbonate, polypropylene, polyetherimide, polyethersulphone or polyphenylsulphone. Preferably the material comprises Tubus Honeycombs™.

According to a second aspect of the present invention there is provided a liner for a body protecting device, the liner comprising:

a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

Preferably the body protecting device comprises a safety helmet. Alternatively, the body protecting device comprises a safety pad.

According to a third aspect of the present invention, there is provided a body protecting device comprising:

a first material bonded to a second material using an adhesive, wherein the adhesive has a melt temperature which is lower than the melt temperature of the first and second material.

Preferably the body protecting device comprises a safety helmet. Alternatively, the body protecting device comprises a safety pad.

Preferably the first and second materials are in a softened state at the melt temperature of the adhesive. This allows thermoforming of the helmet at the melt temperature of the adhesive, as the melted bond allows relative movement between the first and second materials.

Preferably the first material is one of a polycarbonate, polypropylene, polyetherimide, polyethersulphone or polyphenylsulphone material.

Preferably the second material is a plastics material, such as polyetherimide. Preferably the second material is a fibre reinforced plastics material. Preferably the fibres are made from glass or carbon.

Preferably the adhesive is a thermoplastic. Preferably the adhesive is a polyester based material.

Preferably the melt temperature of the adhesive is less than 180°C. Preferably the melt temperature of the adhesive is between 120°C and 140°C.

Preferably the body protecting device is heated during forming to between 155°C and 160°C.

Preferably the body protecting device further comprises a third material and the first material interposes the second and third materials. Preferably the first material is bonded to the third material using the adhesive.

Preferably the first material has an array of energy absorbing cells, each cell comprising a tube.

According to a fourth aspect of the present invention there is provided a method of forming a body protecting device comprising:

bonding a first material to a second material using an adhesive, wherein the adhesive has a melt temperature which is lower than the melt temperature of the first and second material.

Preferably the body protecting device comprises a safety helmet. Alternatively, the body protecting device comprises a safety pad.

Preferably the method includes selecting first and second materials which are in a softened state at the melt temperature of the first material.

Preferably the method includes heating the body protecting device during forming to between 155°C and 160°C.

Preferably the method includes bonding the first material to a third material using the adhesive.

Preferably the first material has an array of energy absorbing cells, each cell comprising a tube.

An embodiment of the present invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Fig. 1 is a perspective view of a safety helmet in accordance with the present invention;

Fig. 2 is a side view of the sandwich panel used to form the helmet of Fig. 1;

Fig. 3 is a side view of the sandwich panel of Fig. 2 in a curved state;

Fig. 4 is a plan view of a known arrangement of cells used for the core of a sandwich panel.

Fig. 5 is a plan view of a tubular array of cells used in the sandwich panel of Fig. 2;

Fig. 6 is a sectional side view of the tubular array of Fig. 5 in a curved state;

Figs. 7a, 7b and 7c are exaggerated plan views of positions of the tubular array of Fig. 6 which are compressed, neutral and extended respectively;

Fig. 8 is a side view of the heating process used for the sandwich panel of Fig. 2;

Fig. 9 is a cross sectional side view of a mould used in conjunction with the sandwich panel of Fig. 2; and

Fig. 10 is the sandwich panel of Fig. 2 in a moulded state.

Referring to Figs. 1 to 3, there is shown a body protecting device in the form of a safety helmet 10. The helmet 10 is formed using a panel 12 which comprises a first material or core 20 which is sandwiched by a second material or outer skin 30 and a third material or inner skin 50. Each of the outer 30 and inner 50 skins are bonded to the core using an adhesive 40.

Fig. 3 shows the sandwich panel 12 in a curved state. In such a state, the material varies linearly from a state of zero stress (in respect of the major planes of the panel 12) at the neutral axis 14 to a state of maximum tensile stress at the exterior face of the outer skin 30 and a state of maximum compressive stress at the interior surface of the inner skin 50. These tensile and compressive stresses cause tensile and compressive strains

respectively. Therefore, there is slippage between the outer skin 30 and the core 20 and the inner skin 50 and the core 20 unless this slippage is prevented by the adhesive 40.

A known core structure is a honeycomb or hexagonal arrangement which is shown in Fig. 4. Each hexagonal cell 60 has a rotation symmetry angle 62, 64 of 60°, 120° and so on, or in other words of $n.60°$, where n is an integer. Therefore, the cell does not have a rotation symmetry angle of 90° and so the overall material is not orthotropic. Also, the material will be anticlastic.

Fig. 5 shows an array of cells for the core material 20 according to the invention. Each cell comprises a tube 22. The tubes 22 are arranged in a close packed array such that the gap between adjacent tubes is minimised. Since each tube 22 has an infinite rotation symmetry angle, the overall tubular array results in a material which is substantially isotropic and non-anticlastic.

Fig. 6 shows the tubular array in a curved state. As described above, the planar stress and strain at the neutral axis 14 is zero and so each tube 22 retains its circular shape as shown in Fig. 7a. At the inner surface 24, the tubes 22 will be compressed in the direction of the curvature, and the profile of the tubes at this position is shown in exaggerated form in Fig. 7b. At the outer surface 26, the tubes will be elongated in the

direction of curvature and the profile of the tubes at this position is shown in Fig. 7c.

It should be noted that, despite compression and extension of the tubes 22, the profile of the tubes 22 when averaged through the thickness of the material 20 will be as found at the neutral axis 14. Also, if there is curvature about an orthogonal axis, this will tend to cause compression and extension in an orthogonal direction, tending to cause the profile of the tubes 22 at any point through the thickness to be as found at the neutral axis 14, although the diameter of the tubes 22 will be reduced at the inner surface 24 and enlarged at the outer surface 26. The tube will in effect be a cone which may even improve the energy absorbing capability of the structure.

The helmet is formed using a suitable thermoforming process. As shown in Fig. 8, the sandwich panel 12 is heated using heaters 70 to a temperature of between 155°C to 160°C, which is above the melt temperature of the adhesive 40.

The sandwich panel 12 is then transferred to a mould as shown in Fig. 9. The male portion 72 of the mould typically has a rubber contacting face and the female portion 74 is typically constructed from aluminium. The mould is at ambient temperature and the transfer of the panel 12 should be effected quickly, preferably in less than 6 seconds to minimise cooling of the panel 12. The male part 72

is then driven towards the female part 74 so that the panel 12 assumes the shape of the mould.

Since the panel 12 has been heated to above the melt temperature of the adhesive, slippage can take place between the outer skin 30 and the core 20, and between the inner skin 50 and the core 20. Cooling of the panel 12 to a temperature below 50°C ensures that the panel has assumed the curved profile and the adhesive once again bonds each of the skins 30, 50 to the core 20. The two parts of the mould can now be separated. The curved panel 12 is shown in Fig. 10.

Various modifications and improvements can be made without departing from the scope of the present invention. For instance, the tubes of the array may be conical and have a cone angle of any angle.

CLAIMS

1. A body protecting device comprising:

a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

2. The body protecting device of Claim 1, wherein the device comprises a safety helmet.

3. The body protecting device of Claim 1, wherein the device comprises a safety pad.

4. The body protecting device of any preceding claim, wherein each tube has a diameter of between 2 and 8 mm.

5. The body protecting device of any preceding claim, wherein the first material has, or can deform to, a large curvature.

6. The body protecting device of any preceding claim, wherein the first material comprises one of polycarbonate, polypropylene, polyetherimide, polyethersulphone or polyphenylsulphone.

7. A liner for a body protecting device, the liner comprising:

a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

8. A body protecting device comprising:

a first material bonded to a second material using an adhesive, wherein the adhesive has a melt temperature which is lower than the melt temperature of the first and second material.

9. The body protecting device of Claim 8, wherein the first and second materials are in a softened state at the melt temperature of the adhesive.

10. The body protecting device of Claim 8 or 9, wherein the first material is one of a polycarbonate, polypropylene, polyetherimide, polyethersulphone or polyphenylsulphone material.

11. The body protecting device of any of Claims 8 to 10, wherein the second material is a plastics material.

12. The body protecting device of Claim 11, wherein the second material is a fibre reinforced plastics material.

13. The body protecting device of any of Claims 8 to 12, wherein the adhesive is a thermoplastic.

14. The body protecting device of Claim 13, wherein the adhesive is a polyester based material.

15. The body protecting device of any of Claims 8 to 14, wherein the melt temperature of the adhesive is less than 180°C.

16. The body protecting device of Claim 15, wherein the melt temperature of the adhesive is between 120°C and 140°C.

17. The body protecting device of Claim 16, wherein the body protecting device is heated during forming to between 155°C and 160°C.

18. The body protecting device of any of Claims 8 to 17, further comprising a third material, wherein the first material interposes the second and third materials, and wherein the first material is bonded to the third material using the adhesive.

19. The body protecting device of any of Claims 8 to 18, wherein the first material has an array of energy absorbing cells, each cell comprising a tube.

20. A method of forming a body protecting device comprising:

bonding a first material to a second material using an adhesive, wherein the adhesive has a melt temperature which is lower than the melt temperature of the first and second material.

21. The method of Claim 20, including selecting first and second materials which are in a softened state at the melt temperature of the first material.

22. The method of Claim 20 or 21, including heating the body protecting device during forming to between 155°C and 160°C.

23. The method of any of Claims 20 to 22, including bonding the first material to a third material using the adhesive.

24. The method of any of Claims 20 to 23, wherein the first material has an array of energy absorbing cells, each cell comprising a tube.

ABSTRACT

A body protecting device, such as a safety helmet or safety pad, comprises a first material having an array of energy absorbing cells, wherein each cell comprises a tube.

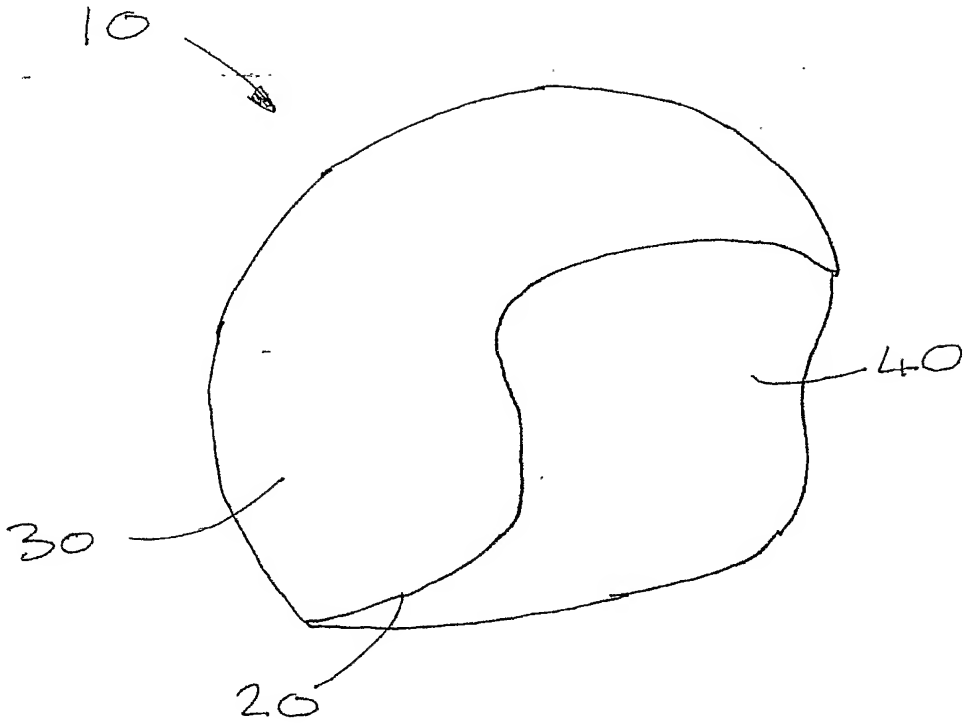


Fig 1

Fig 2

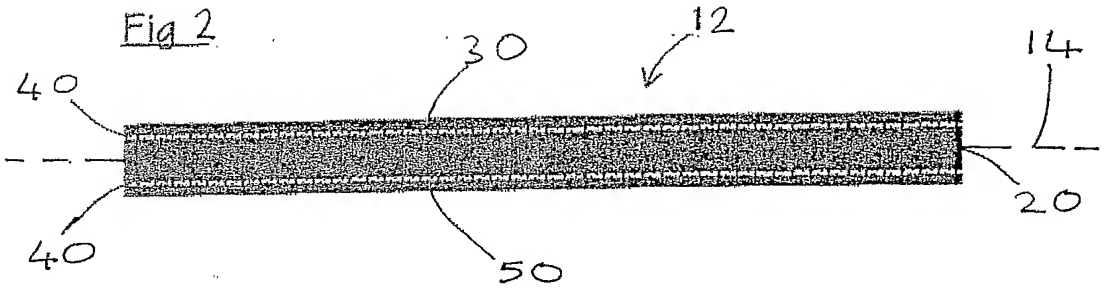


Fig 3

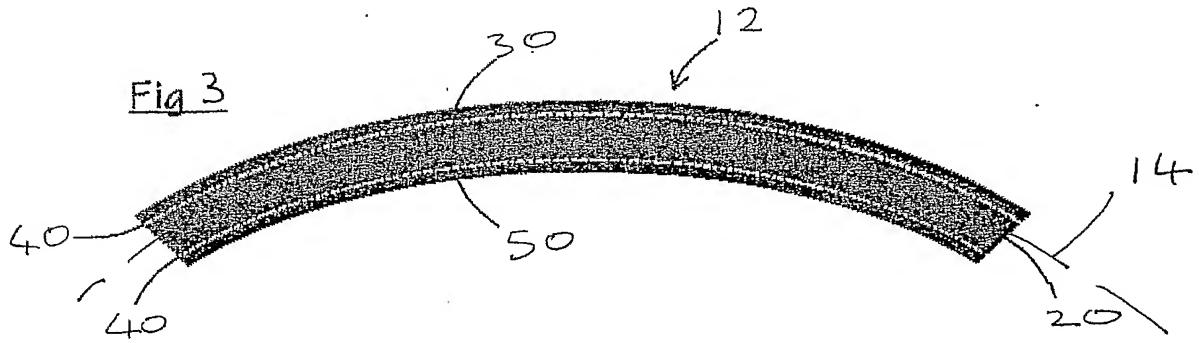


Fig 4

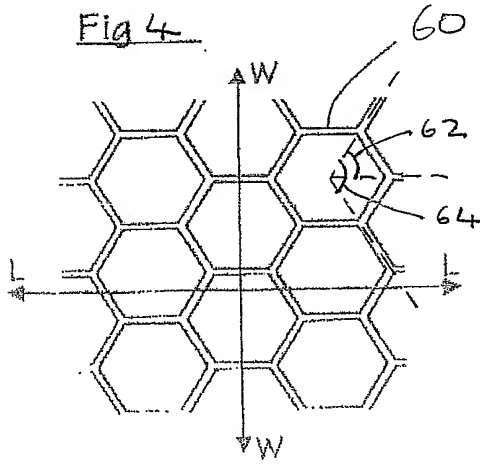


Fig 5

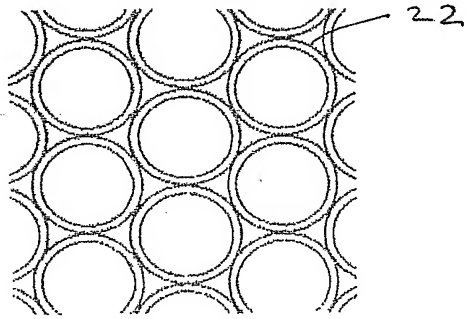


Fig 6

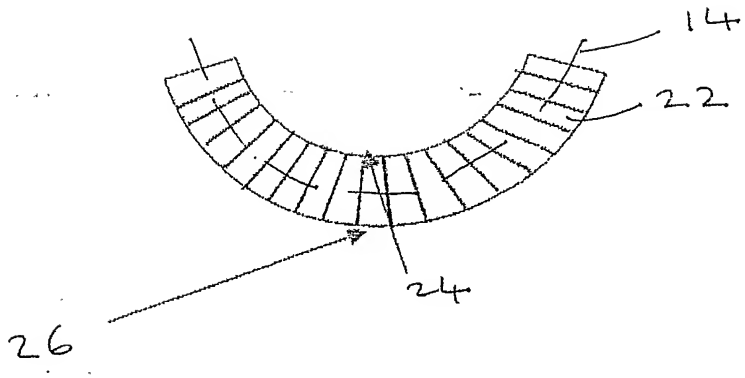
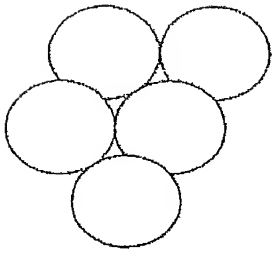


Fig 7a



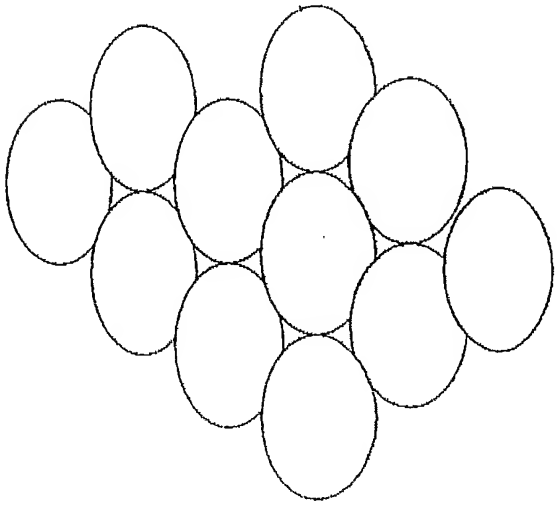


Fig 7b

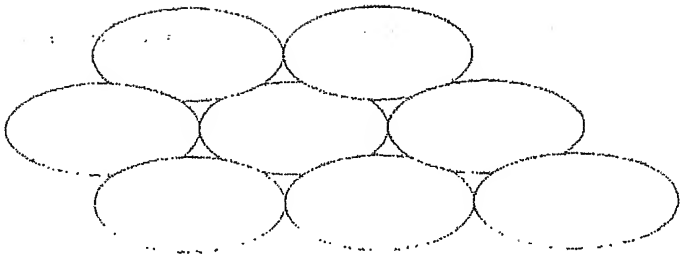


Fig 7c

Fig 8

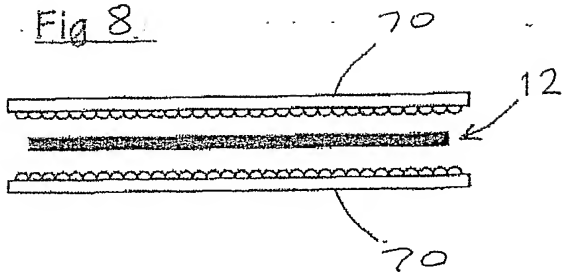


Fig 9

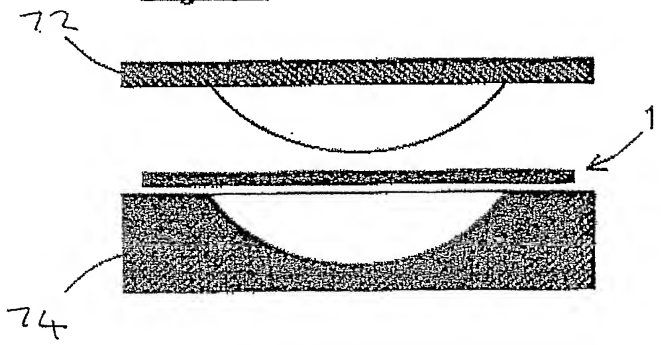


Fig 10